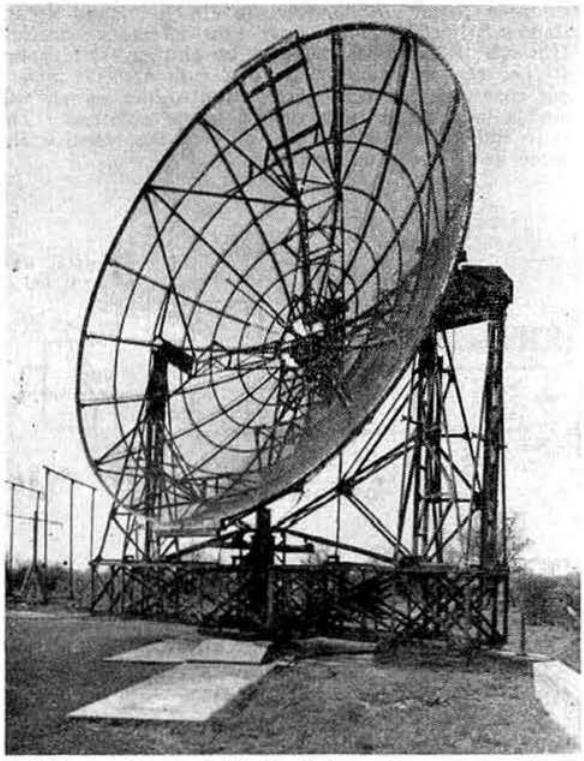
Radio Astronomy and the Radio Amateur†

Part I

By R. C. JENNISON, Ph.D., B.Sc. (ex-G2AJV)*



A 30ft steerable paraboloid for hydrogen line measurements on 21 cm. Note the fine mesh of the bowl and diminutive aerial at the focus. The Yagis in the background (left) are used for meteor echo techniques.

It is now more than seven years since Martin Ryle (then G3CY) read a paper to the Society under the title "Radio Signals from the Sun." That paper—one of the very first delivered to a scientific body on the subject of Radio Astronomy—gave members an inkling of the tremendous strides which were then being made in this new field. Ryle's original work at the Cavendish Laboratory, Cambridge, is now widely acclaimed.

In the article which follows Roger Jennison (until recently G2AJV) seeks to bring our knowledge of Radio Astronomy up to date.

IT is hoped that this brief account may interest and encourage radio amateurs who are fascinated by the prospect of helping to unravel a little of the mysteries of the universe, and also those who enjoy just dabbling with electronics as a break from QSOs.

An acquaintance with the general picture of the astronomical universe is necessary if one is interested in pursuing the subject of radio astronomy, but there is certainly no need for every radio astronomer to be an astrophysicist. In this article, before very briefly reviewing some of the more simple and interesting of the present techniques, and before discussing the trials and tribulations that may be in store for the radio amateur, we shall first try to obtain a very broad picture of the universe around us and of our own place in it.

The Astronomical Universe

In this peep at the Universe we shall start with the solar system and a few facts which we all know and then work our way out to the stars and galaxies beyond.

The Moon revolves around the Earth at a mean distance of about 200,000 miles. As the velocity of light is 186,000 miles per second, moonlight takes about one second to reach us; radar echoes sent back to the Earth from the Moon therefore take about two seconds in transit. The Moon and the Earth together revolve around the Sun, as do the remainder of the planets. All the planets revolve around the Sun in elliptical orbits. The mean distance from the Sun to the Earth is about 90,000,000 miles and sunlight takes about seven minutes to reach us; the distance from the Sun to the outermost planet, Neptune, is approximately 3,000,000,000 miles.

The orbits of the planets are crossed by the much more elongated orbits of the comets and meteor streams. Unless we spend our lives star-gazing, most of us are lucky if we see one comet in a lifetime, but meteors may be seen quite frequently, especially on clear nights in the Autumn. Meteors are tiny pieces of compressed dust, about the size of a pin head. This dust is distributed in a continuous thin stream all the way round the orbit and it is thought that it may be the debris from disintegrated comets. As the orbits of the meteor streams are narrow and drawn out, they each cut the orbit of the Earth twice during the Earth's yearly voyage round the Sun. On entering the Earth's atmosphere their velocity is of the order of 10 or 20 kilometres a second and they burn up at a height of about 100 kilometres to leave a visible streak by which we see them, and a column of ionised gas which enables us to detect them by radar. It will be apparent from the diagram in Fig. 1 that the Earth's orbit always intersects that of a particular meteor shower at the same point, or pair of points. For this reason each meteor shower occurs regularly each year, and, furthermore, the trajectories of all the meteors in a particular shower are roughly parallel; as seen by an observer on Earth they therefore appear to radiate from a single point in the heavens—called the *radiant* of the meteor shower. All the meteor showers are known by the constellations wherein their radiants appear to be situated, e.g. the Perseids and the Leonids from the constellations of Perseus and Leo respectively. By measuring the velocity of a meteor as it enters the Earth's atmosphere it is possible to compute the shape of its orbit. If the velocity exceeds a certain definite value, known as the parabolic limit, the orbit of the meteor can no longer be an ellipse making a continuous circuit

†Based on a lecture delivered to the Society at the Institution of Electrical Engineers, London, on February 25, 1955.

**Jodrell Bank Experimental Station, Lower Withington, Macclesfield, Cheshire.*

round the Sun, but must be a hyperbola; this means that the particular meteor is not a member of the solar system, and, had it not been intercepted by the Earth, it would have made just one swoop round the Sun and then disappeared again away amongst the stars.

If we journey out beyond the solar system we have to travel about 4 light years before we encounter the nearest star. Now a light year is about 6,000,000,000,000 miles. The scale can be visualised if we consider the Sun as the size of a billiard ball in London; the nearest star would then be an object of the same order of size in Edinburgh! The separation between the Sun and its neighbours is typical of that between all the stars in our Galaxy; yet our Galaxy contains about 100,000,000,000 stars. All these stars are distributed in a flat disc having a spiral structure and a hub at the centre, rather like a gigantic catherine wheel except that, instead of one spiral arm, the Galaxy has several. The solar system is situated in one of these great tentacles about two-thirds of the way out from the Galactic nucleus, or hub, to the edge of the disc. The actual distance of the Sun from the nucleus is about 2×10^{17} miles. When we look into the sky on a clear night and see the Milky Way we are actually seeing the stars in

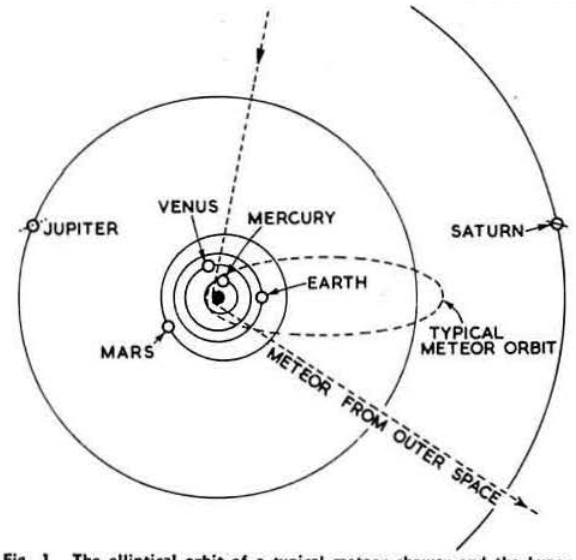


Fig. 1. The elliptical orbit of a typical meteor shower and the hyperbolic trajectory of a meteor from outer space.

the plane of the disc. Looking to either side of the Milky Way the stars appear less numerous as we are looking outwards through the nearer stars at right-angles to the plane of the disc. Why, the reader may ask, do we not see the bright nucleus of the Galaxy? The answer is that we do, but only on radio wavelengths; on optical wavelengths it is obscured by clouds of dust. These dust clouds are similar in form to ordinary earth-bound clouds but are on the average about 30 light years across. The distance between each particle of dust may be many miles, but the aggregate is sufficient to black out all the stars shining from behind. The dust clouds are confined to a very thin sheet in each spiral arm coincident with the plane of the Galaxy. When we look up at the Milky Way they appear to us as holes in the belt of stars. Also roughly coincident with the dust clouds there is a thin sheet of gas running through the Galaxy, which is almost entirely hydrogen and has a density of about one atom per cubic centimetre; that is, about 10^{-19} the density of air, yet it is one of the chief sources of emission of radio waves.

Our own Galaxy with its myriads of stars is just one of millions of similar galaxies scattered through space. They stretch to the limit of the observable universe, and there may be many more than the most intensive searches with the largest telescope have yet revealed. Though in some parts of the sky these galaxies occur in clusters, they move about to a large extent independently of each other. As the distance between each galaxy is not many times the size of each, collisions between them may sometimes occur. A striking example of such a cosmic catastrophe has been identified with the radio source in Cygnus, the second strongest of the radio "stars." The distance to the Cygnus radio source is 100,000,000 light years, the distance to the Andromeda nebula, the nearest of the external galaxies, is about a million light years.

Radio Astronomy Techniques

Equipment for the detection of meteor echoes may be either c.w. or pulse operated. In the former case the meteor reflections give rise to whistles lasting a fraction of a second; the radiants and velocities of the meteors in a particular shower may be determined by using a single receiver with two aerials pointing at right-angles. The measurement of the corresponding quantities for a single meteor, however, requires a more complex system of three receivers spaced at the points of a triangle about a mile apart. Pulse techniques require a peak pulse power of the order of a kilowatt and enable measurements to be more simply performed from one station, but as the meteor trails only reflect efficiently radio waves longer than about 3 metres, amateur work in this sphere must be largely confined to c.w. operation. The same equipment as that used for meteor echoes may also be used for detection of the Aurora Borealis; in this case the rays, curtains and streamers of the aurora consist of gas ionised to a similar degree to that in meteor trails, but the ionisation is less fleeting and the echoes persist for long periods, during which they usually show progressive motion in the direction of the magnetic poles.

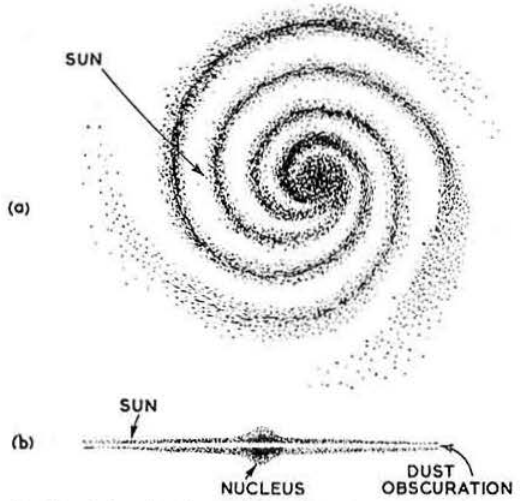


Fig. 2. The Galaxy in plan and elevation. Note the restriction of the obscuring matter to the plane of the system. The distance from the Sun to the centre is about 2.10^{17} miles. There are about 10^{11} stars in the Galaxy and there are millions of other similar galaxies distributed throughout space.

The aerial requirement for work on meteors and the aurora is essentially one Yagi. The optimum amateur band at the present time is 28 Mc/s.

Radio echoes from the Moon require a minimum mean power of about a kilowatt, preferably pulsed with a pulse length of the order of milliseconds in order to allow time for the echoes from the more distant parts of the Moon to be reflected back with those from the nearer central parts and thus give a reinforcement of the received signal. Lunar echoes suffer a severe rotation of the plane of polarisation of the radio waves during their passage through the ionosphere, and for consistent results it is advisable to use a circularly polarised aerial array with an aperture of at least 150 square metres. Much more complex techniques than those at present in use are required in order to glean useful information about the Moon from radio echoes. As shying pulses at the Moon is at the best of times a costly business, I would not recommend it to any amateur.

Radio noise signals from the Sun and the Galaxy give much more scope for the amateur with restricted means, for the requirements for simple but useful experiments in this field are both less costly and less cumbersome. In order to detect the solar radio emission anywhere in the range of frequencies from 30 to 200 Mc/s, a simple dipole connected to a stable receiver will suffice. The bandwidth of the receiver should be as large as possible, consistent with the avoidance of man-made interference—5 Mc/s is excellent but 100 kc/s will suffice—and the detector circuit should feed a time constant of about one second in order to integrate the noise output. If the detector has a square law characteristic then the increments of d.c. output are directly proportional to the increments of noise power at the aerial, but the noise ripple on the d.c. output, tending to mask very small changes of level, is inversely dependent upon the square root of the product of the bandwidth and integration time. In order to detect very small changes of noise entering the aerial one can therefore either use a very large aerial in order to increase the increments at the input, or one can more simply and cheaply use a broad band receiver having a large time constant at the detector (Fig. 3 (a)). A receiver has recently been constructed for use in this field in which the bandwidth is 20 Mc/s and the integration time ten hours. This, however, is most exceptional and requires fabulous stabilization of all the equipment. A dipole aerial connected to a simple superhet having a bandwidth of 0.5 Mc/s and an integration time of one second will give a clearly visible increase in output as the Galaxy moves through the aerial beam, but as the beam width is so large for a dipole the receiver itself must stay constant in gain for a very long time, practically a whole day. The detection of the radiation from the quiet Sun places similar requirements on the stability of the receiver if only a dipole aerial is used, though the very much stronger bursts of noise from sunspots and solar flares, when they occur, may easily be detected on an unstabilized receiver. Preferably, both the h.t. and l.t. supplies should be stabilized for all this work, though there are a number of circuit arrangements for the receiving equipment which only give an output for noise actually entering the aerial. In one of these methods (Fig. 3 (b)), the input of the receiver is continually switched between the aerial and a noise diode, whilst the output is switched in synchronism to feed a corresponding difference signal back to the filament of the noise diode; the noise diode therefore is always automatically maintained at the same level as the noise entering from the aerial. The level of the latter may be directly observed on a milliameter in the anode circuit of the diode. An entirely different method of obtaining an output from only the noise signals entering the aerial is to use a phase switched, or preferably a phase rotated, interferometer. We shall return to this method later.

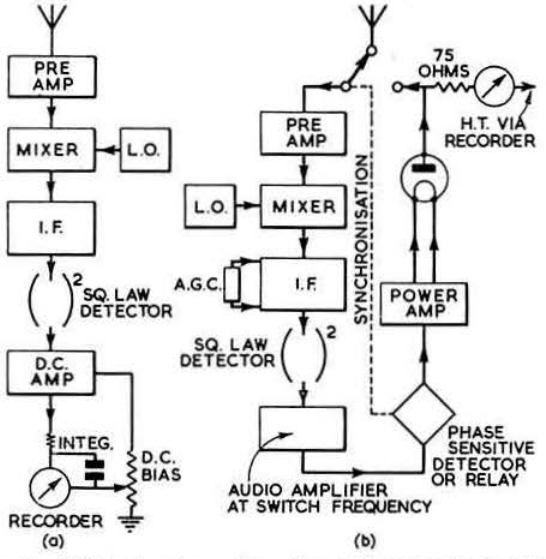


Fig. 3. (a) Simple noise receiver. The condenser across the meter is shown to represent an integration time of about 2 seconds obtained in practice from, say, a 1 MΩ resistance feeding 2 μF at the input of the d.c. amplifier or similar high impedance point. The gain of the d.c. amplifier should be 10 to 100. (b) A very stable and sensitive arrangement which self adjusts to the aerial noise. 3 db is lost in the switching process, but measurements of less than 1/1000 set noise are easily attainable.

Very simple aerial systems and equipment are used for the detection of the ionospheric scintillations which occasionally modulate the signals reaching the Earth from the radio stars. These scintillations correspond to the twinkling of ordinary stars and are due to the inhomogeneity of the upper layers of the Earth's atmosphere. If, say, a single Yagi is connected to a simple receiver tuned to a frequency between 30 and 100 Mc/s, the radiation from the Galaxy will be detected and the noise output of the receiver will be found to rise during the transit of the Galaxy through the aerial beam. About once or twice a week it may be observed that there also occurs a rapidly fluctuating signal lasting for a time comparable with the motion of a celestial body through the aerial beam. These signals will be due to the radio stars in Cygnus and Cassiopeia, the two most intense of the radio sources, but the fluctuations come from the F layer of the ionosphere, not from the radio sources. By comparing the records of twinkling received at two or three stations spaced about a mile apart it is possible to determine the size and shape of the irregularities in the ionosphere and also the speed at which they move. This simple experimental technique has contributed greatly to our knowledge of the ionosphere during the last few years and general surveys are now being undertaken by small institutions and amateur bodies all over the world.

To be concluded next month

Two Metre Activity in Kenya

FROM the *F.O.C. News-letter* we learn there is a great deal of 2 m activity in Kenya, and that efforts are to be made to capture the 2 m world record. Any further news would be welcomed.

Radio Astronomy and the Radio Amateur†

Part II

By R. C. JENNISON, Ph.D., B.Sc. (ex-G2AJV)*

THE large radio telescopes which have recently been constructed have the great virtue of enormous collecting power, but they are far beyond the reach of any amateur's pocket and are quite unnecessary for the study of many of the problems in radio astronomy. The fine beamwidth, or high resolving power, of the very large aerial systems may be obtained with only two dipoles if they are connected as an interferometer, that is to say they are connected together by equal lengths of feeder but are spaced many wavelengths apart. This arrangement was referred to by Martin Ryle in the *Proceedings of the R.S.G.B.* some years ago. The system of two aerials gives a polar diagram consisting of a number of fine lobes, the width of each being half that which would be obtained in the main beam of a single aerial system of such a size that it filled all the space between the two dipoles! The transit of a radio star through an interferometer aerial beam gives a bump caused by the broad polar diagram of the individual aerials, modulated by very clearly marked fringes as the source passes through the interference pattern of fine lobes (Fig. 4). If the radio star has an angular diameter smaller than the width of these lobes the modulation of the bump by the fringes will be 100 per cent, but if the source is larger than the lobes the modulation will be reduced and may not even appear. The interferometer system therefore is ideally suited, not only for the detection of very small regions of emission, but also for their accurate positioning and the measurement of their size.

Interferometer techniques have been greatly improved during the last few years. One great improvement, due to Martin Ryle, was to incorporate a switching mechanism whereby a half wavelength of feeder was rapidly and periodically inserted in one of the two main feeders; the output of the receiver was then arranged to record only the difference of noise level between these two states by inserting a synchronized relay in series with the meter (Fig. 5). The great advantage of this method is that stability requirements are considerably reduced and the receiver may be given heavy a.g.c. without appreciably affecting the size of the fringes in the output. A more recent and equally important improvement has been to rotate the phase of one of the two limbs of the interferometer and thus to generate artificial fringes in the presence of radiation from a small source; with this arrangement the natural

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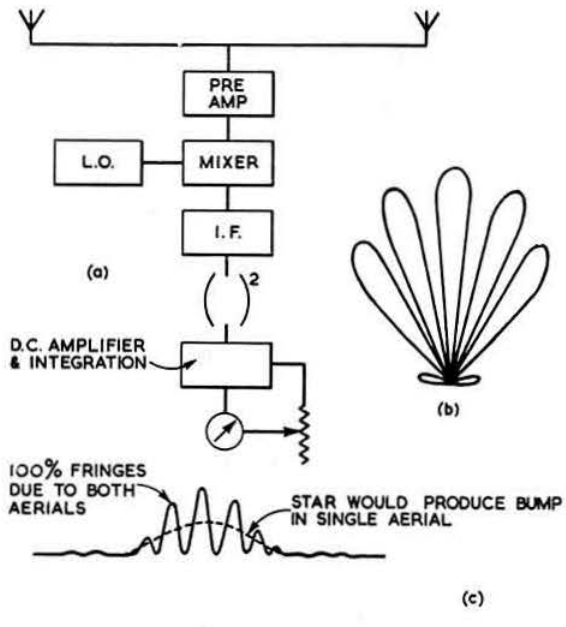


Fig. 4. (a) The simple spaced aerial interferometer. (b) Polar diagram. The polar diagram is crossed by the fine interference lobes between the two aerials. (c) Reception pattern on the recording chart. The bump due to the star crossing the aerial polar diagram is modulated by the interference fringes.

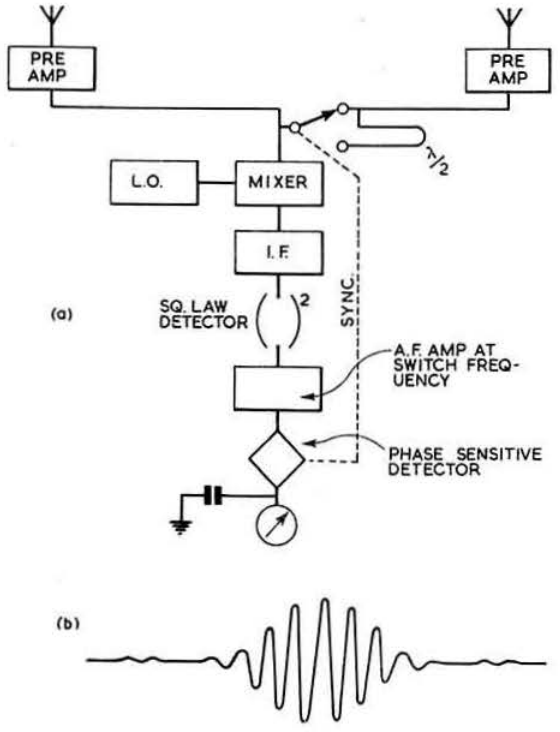


Fig. 5. (a) The phase switched interferometer. A half wavelength of line is switched in and out of one aerial feeder and the addition of the signal in this channel with that from the other aerial is compared in either position. (b) The resulting record due to the passage of a source through the aerial beam. Note that there is no output in the absence of a source.

fringes may be slowed down or speeded up at will, whilst they may also be produced when the two aerials are on a north-south baseline, a condition which gives no fringes with a simple interferometer. It is permissible to insert separate pre-amplifiers in each aerial lead and to use separate mixer stages so that the two channels may be united at the intermediate frequency, but if such an arrangement is used it is essential to use the same local oscillator to feed both mixers (Fig. 6).

The author recently constructed an interferometer in which the two aerials were once spaced twelve miles apart and this gave excellent results with a beamwidth equivalent to only 30 seconds of arc. This interferometer used a radio link to unite the two channels and in such an arrangement it is necessary to transmit back not only the signal in the distant channel but also all oscillator frequencies used to form the finally transmitted signal. These frequencies must then either be applied to the "home" channel or subtracted from the distant channel at the receiving end.

The spectrum of the radiation from the Galaxy increases very markedly on the lower frequencies, and as we are still near the sunspot minimum the state of ionization of the upper atmosphere is such that, provided we observe the Galaxy when it is almost overhead, the noise can be easily detected on frequencies as low as 10 Mc/s. The spectrum of the individual radio "stars" also rises with decreasing frequency, though not as sharply as that from the Galaxy. Cassiopeia and Cygnus may also be detected at the present time on 10 Mc/s. These two radio "stars," the strongest in the sky, transit at upper culmination, i.e. nearest overhead, about 5 degrees north and 15 degrees south of the zenith respectively. The time of day when they are in this position varies with the time of year, for the stars complete one circuit round the Pole Star in one siderial day, which is four minutes shorter than the ordinary day, so that the time of transit of a particular star moves four minutes earlier every day. If you want to work out when to expect them to transit, Cassiopeia transited at about 11 a.m. G.M.T. on April 1, whilst Cygnus transited at about 7 a.m. G.M.T. on the same day; if 4 minutes are allowed for every day since April 1, the time of transit can be calculated all the year round.

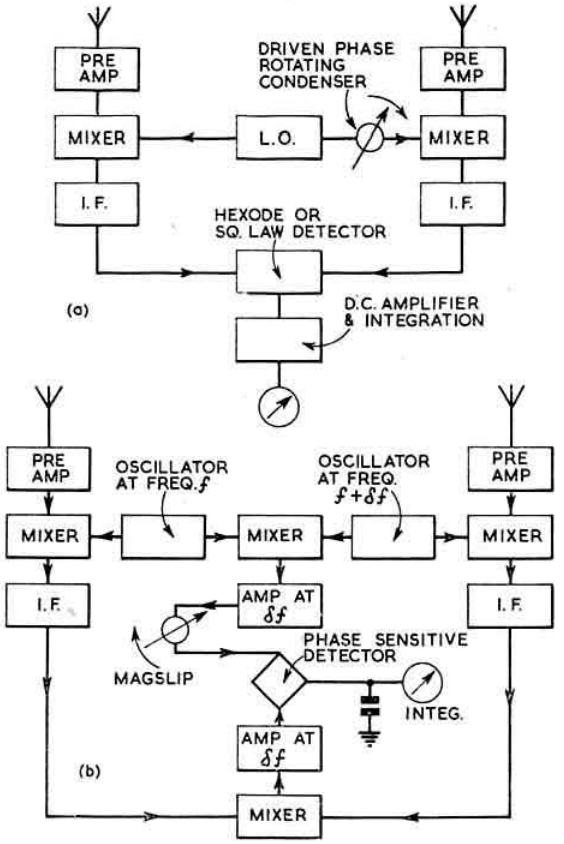


Fig. 6. (a) Simple phase rotated interferometer. This gives a similar reception pattern to that in Fig. 4 (c) but with fringes of any desired period. A phase switch similar to that in Fig. 5 (a) may also be included in one aerial lead, or at i.f., or in the l.o. line, to give a pattern of the form in Fig. 5 (b) but with controlled fringes. (b) A more complex rotating lobe interferometer which directly gives a pattern of the form in Fig. 5 (b) with fringes of any desired period. The difference in frequency between the two crystal oscillators, δf, is about 1000 c/s.

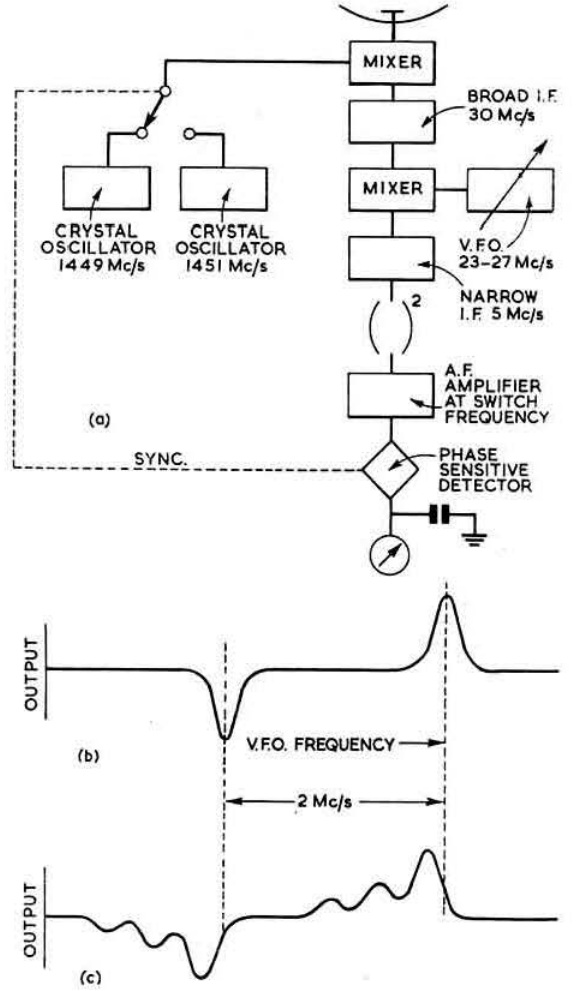


Fig. 7. (a) 1420 Mc/s hydrogen line receiver. (b) Output as v.f.o. is swung to tune receiver through the line on 1420 Mc/s. (c) Output when line is complex. This record is typical of the radiation from three spiral arms when looking along the plane of the Galaxy. The different line-of-sight velocities result in different frequency shifts.

An entirely different type of signal to that already described may also be detected from the Galaxy. This is the hydrogen line which occupies only a very narrow frequency band centred on 1420 Mc/s. This frequency is emitted by the neutral hydrogen atoms in the Galaxy when the nucleus of each atom decides to spin the other way round. The very important point about this signal is that it gives us an estimate of the speed at which different parts of the Galaxy are moving, and from our knowledge of the approximate shape of the latter we are then able to fill in the accurate details of its structure. The reason that we are able to measure the velocities of the transmitting regions from this signal is that the motion of the transmitter shifts the frequency of the transmitter. This is exactly the same phenomenon as that which causes the note of a locomotive whistle to apparently change as the train passes through a station; if we measure the change of note we can calculate the speed of the train.

The most usual form of the apparatus used to study the hydrogen line consists of a receiver in which the noise in two channels is compared in level whilst both channels are tracked together over a frequency range from about 1418 to 1422 Mc/s. The line appears first in one channel and then in the other. The output of the receiver is first deflected in a positive and then in a negative direction, in each case tracing the contour of the line (Fig. 7). The minimum aerial requirement for satisfactory results from the hydrogen line is probably a 10 ft paraboloid. This paraboloid would have to be accurate to a tolerance of 1 in. but could be made very simply by stretching chicken mesh across three or four hoops rigidly fastened to a frame in the form of two Vs at right-angles joined together at the apex.

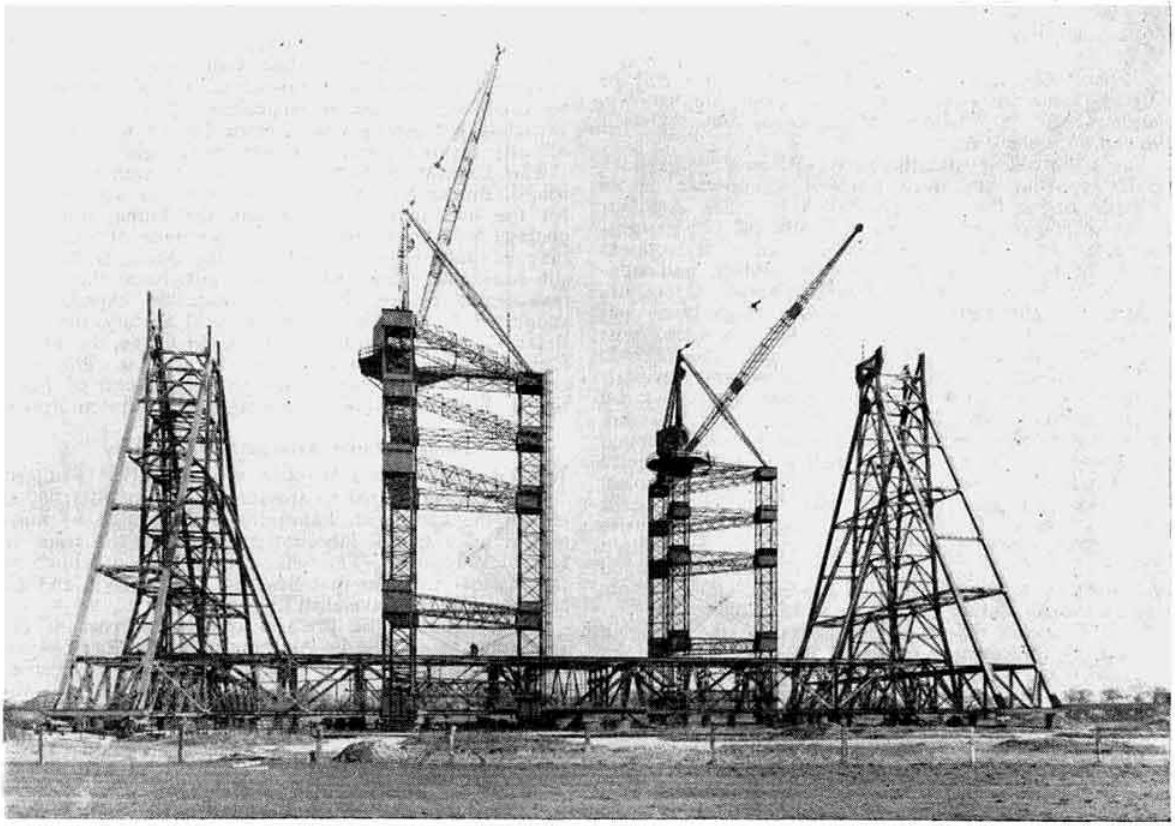
Signals from the planet Jupiter have recently been detected. These signals are very like ordinary atmospheric interference and only occur below about 30 Mc/s. They are very strong in the 14–20 Mc/s range and may be detected about one night in three on a very elementary receiver.

Amateur Research

For all this work the greatest snag as far as most amateurs are concerned will be an inherently unsuitable site. As most of the work requires the lowest possible noise level, any QTH within 5 miles of a town will be in danger of being swamped by local QRM.* If, however, a suitable site is available, many of the techniques that have been briefly described are quite within the scope and the pocket of the average amateur.

For those who are interested in the various radio noise phenomena the problem of recording the noise level represents the most difficult stumbling block.

*Interferometers with aerial spacings in excess of 50λ are exceptional, and may possibly prove satisfactory, if space is available, in a built-up area.



The 250ft radio telescope at Jodrell Bank under construction. In this photograph the two towers are almost complete. The bowl will be slung between them, pivoted at either end so that it may be controlled in elevation. The whole structure shown revolves on bogeys beneath the two towers on a circular railway track 350ft in diameter. Note the two men standing together on the main cross girder, just to the left of centre.

Don't be disheartened by the enormous cost of commercial pen recorders; I made one myself when a schoolboy out of odd bits of Meccano, and I dare say many others have done the same. The great secret here is that the recorder itself does not have to be sensitive, for it is not difficult to supply it with power from the equipment. The pen may be made by drawing a piece of glass tubing over a gas flame; methylene blue, obtainable at most chemists, is very suitable as an ink. With regard to the rolls of paper, there is, of course, a very obvious source. Usual chart speeds are about 6 in. an hour for work on the radio "stars" or the Galaxy, and 3 ft an hour for work on the ionosphere scintillations. The most suitable recording system for meteor, aurora and Moon observations is a cathode ray tube, though the meteors can actually be heard on a communications receiver by listening to an unmodulated c.w. signal (the whistles caused by the meteors are due to the fact that the signal reflected from the meteor trail suffers a Doppler shift, like the train whistle, and beats with the transmitted signal to produce an audible sound).

Aerial systems should present little difficulty, especially for country dwellers, and I would strongly recommend an interferometer system to those interested in noise work. Keep the noise factor of the receiver as good as possible. Surplus 6AK5s are not very dear and give excellent results if triode connected in a cascode with, say, a 6J6. Below 80 Mc/s a grounded grid input stage will suffice, and below 40 Mc/s a decent pentode is all that is needed.

It is a common failing of most of the big research establishments that the larger experiments are undertaken at the expense of numerous smaller ones which may yield equally valuable results. There is considerable scope for the keen amateur with a small interferometer, or even a most elementary single array, in many of the branches of radio astronomy. A few of the most important simple experiments are a study of the polarization of the sources; their spectra, especially on frequencies below 30 Mc/s; the size of the sources at centimetre wavelengths; the study of the ionosphere scintillations; and all aspects of the ever changeable Sun.

Given a suitable site and an average amount of amateur equipment (especially the junk box), all that is required is a little initiative and ingenuity. Remember that throughout the history of science, the simplest and cheapest apparatus has often yielded the best results. Try your luck at the stars: they're easy, but, unless you hold a W call, don't reach for the Moon!

Gough Island Scientific Expedition

MEMBERS of the eight-man scientific expedition to Gough Island, a lonely, uninhabited strip of land about eight miles long and 260 miles south-south-east of Tristan da Cunha, leave England at the end of August. The party will be taken from Simonstown, South Africa, in a frigate of the Royal Navy towards the end of September.

The radio officer with the party will be P. J. Mullock (G3HPM) who has been licensed to operate as an amateur under the call-sign ZD9AD. The Amateur Radio equipment will include a Panda PR-120-V transmitter, an Eddystone 680X receiver, six 45 ft sectional masts, 3,000 ft of various types of feeders, and sufficient wire for a variety of aerial systems. Operation, expected to commence in the middle of October, will be on all bands covered by the transmitter with, most likely, emphasis on 21 Mc/s phone and c.w. ZD9AD will also operate on Top Band if the necessary crystals in the range 900-1000 kc/s (half signal frequency) can be obtained before the Expedition leaves England. Offers from members, on a loan basis, would be much appreciated. It is hoped that A.R.R.L. will recognize Gough Island as a separate country for DXCC purposes.

Mr. Mullock states that he will not reply to calls within 10 kc/s of his own frequency. Stations who call ZD9AD while he is in contact with another station will be blacklisted. QSL cards have already been printed and will be sent out via the R.S.G.B. QSL Bureau. Incoming cards should be sent the same way.

Mr. Mullock's official duties as radio operator will include the transmission of important daily metereological reports to the South African Weather Bureau. Permission has been granted for the transmission of official traffic in the amateur bands as far as Tristan da Cunha only. The communication equipment includes a Pye PTC790 60 watt crystal controlled h.f. station (transmitter and receiver) powered by a 2 kW Petter-Diesel generator supplied by Dale Electrical, Ltd. The generator provides standard mains voltages.

Other equipment includes an Army 62 set for internal communications on the island, v.h.f. walkie-talkies for survey work and two tape recorders—a Vortexion and a Boosey & Hawkes—for recording scientific reports, survey notes, bird songs and animal noises. An electric fence for warding off sealions is also being taken!

Mr. Mullock will act as temporary Postmaster on the island. Members who are also stamp collectors may be interested to know that Tristan da Cunha stamps will be used with a special Expedition date stamp. It is expected that fishing vessels from Tristan will call periodically during the scientists' stay on Gough.

The Expedition hopes to spend six months on the island, during which it will be surveyed and mapped for the first time. In addition, the fauna, flora and geology will be studied. The importance of this work may be judged by the fact that the island is the only sub-Antarctic island which has not been thoroughly investigated before. For this reason, the expedition is supported by the Royal Geographical Society, the Scott Polar Research Institute, the Colonial Office, the Mount Everest Foundation and many other bodies. The Society's Patron, His Royal Highness the Duke of Edinburgh, K.G., is taking a keen interest in the enterprise.

Mullard Radio Astronomy Laboratory

FROM the *News Chronicle* we learn that Mullard, Ltd., have offered to provide the sum of £100,000 to enable the Cavendish Laboratory, Cambridge, to build and equip a special laboratory devoted to the study of Radio Astronomy. The offer is made as a tribute to the pioneer work in that field by Martin Ryle and his colleagues at the Cavendish Laboratory.

As recalled in the preface to the first part of Dr. Jennison's paper "Radio Astronomy for the Radio Amateur" (July 1955, issue) Martin Ryle (who is licensed as G3CY) was the first to deliver a lecture to the Society on the subject of Radio Astronomy. The lecture was given more than eight years ago at the Institution of Electrical Engineers.

Radio Navigation by the Sun

ACCORDING to a report in *Industrial Communications*, quoted by the *I.T.U. Journal*, equipment has been developed for radionavigational use which depends upon the reception of radio energy emitted by the Sun.